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Classification and characterization of a cultivated tropical peat in Sepang district of Selangor, Malaysia

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ABSTRACT

The classification of tropical peat soil is crucial in agriculture industry and there is a need for a classification system for tropical peat especially in Malaysia to suit local conditions. Therefore, the aim of this study was to evaluate the applicability of the revised classification system (Malaysian soil taxonomy) for the classification of the tropical peat in Sepang, and compare with the international system of the USDA and WRB. This study was conducted at TKPM Ulu Chucoh, Sepang and the study area covers about 9 ha. Three soil profile pits was excavated within the study area using a transect approach based on the topography of the land, soil profile description, morphological properties of the soil profile were described. Soil samples at all identified horizons were collected and processed for laboratory analysis. The colour of the peat in the study site vary from very dark brown (10 yr, 3/2) as a result of high content of organic matter at the top soil to dark gray (10 yr, 5/1) due to gleization condition in all the soil profiles. The rate of decomposition of plant litters and debris varied with depth and location of the soil profile ranging from fibric−hemic−sapric which was influenced by the depth of the ground water table fluctuation. The pH ranged from 3.16−5.11, organic matter content ranged from 12.27−29.43%, and bulk density from 0.22−0.24 g cm^{-3}. The exchangeable bases and the base saturation were low across the study area. The variation in the properties of the peat across the study area was due to the eutrophic process, botanical origin, decomposition degree, ground water composition and depth, and the land use management. The peat is classified as dystric peat due to the acid reaction. Results showed that the peat is moderately to marginally suitable for annual and perennial crops based on the soil properties.

1. INTRODUCTION

The peat or organic soil are those soil in which organic soil material (OSM) forms most portion of the upper 100 cm of the soil (Wahid *et al.,* 2013). Of the world's total peatland, the tropical peat covers about 8% (Maltby and Immirzi, 1993), in which 60−70% of the total tropical peat is found in Malaysia and Indonesia (Veloo *et al.,* 2014). The peat (soil) is formed through the slow decomposition of organic matter which is accumulated from plant debris over years. Peat composition differs from locations and the factors (origin fibre content temperature climate and humidity amongst all) responsible for the variations (Huat, 2004). The organic contents are essentially the plant remains whose rate of decomposition is slower than the rate of accumulation. The peatland is classified either as tropical highland or tropical lowland (Temperate peat and tropical peat, respectively). The topical peatland became difficult to classify due to their floristic diversity and their stratigraphic, hydrological and geomorphological variations (Malawska *et al.,* 2006) and few studies have classified the tropical peat (Andriesse, 1988; Yonebayashi *et al.,* 1992). However, in the temperate zones, the peatland has been well classified and quantified, while in the tropical region, studies on the classification of peat resources is still lacking (Veloo *et al.,* 2014). The existing classification system used for the temperate peats (von post system) has failed in characterizing the tropical peat (Wüst *et al.,* 2003), because the tropical peats has various tree species with different root penetration, high rate of biomass production and decomposition. The need for a classification system was highlighted by Wüst *et al.* (2003), and this led to

Paramananthan (2010a) to modify the USDA classification system to suit the local conditions considering the peat depth, presence of wood, rate of decomposition, and the underlying mineral substratum. In Malaysia, before the revised edition by Paramananthan (2010a), different tropical peat classification system was developed based on different criteria. Coulter (1950), classified the peat based on the fertility status (eutrophic, oligotrophic or mesotrophic groups). Law and Selvadurai (1968), classified the peat based on the carbon loss by ignition and depth of the peat. Meanwhile, from the classification based on the depth of the peat, Paramananthan and Eswaran (1984), proposed a different classification based on the thickness of the peat such as shallow (50−100 cm), moderate (100−150 cm), deep (150−300 cm) and very deep (>300 cm). The peat or organic soil was further classified based on the topography, botanical origin, genetic processes, physical and chemical properties (Andriesse 1988). However, the modified classification system for the tropical peat was tested in Malaysia and Indonesia respectively which shows to work well, and a total of 700,000 ha of the tropical peatland in the southeast Asia was evaluated using the modified system (Paramananthan, 2010a) till date (Veloo *et al.,* 2014).

Malaysian peat classification system was developed by modifying the USDA system, thereafter applied to classify most tropical lowland peat to suit the local conditions (Hajon *et al.,* 2018). The main aim of the present study was to evaluate the applicability of the revised classification system (Malaysian soil taxonomy) as modified and proposed by Paramananthan, (2016) for the classification of the tropical peat in Sepang district (Selangor, Malaysia), and further compared with international systems of the United State Department of Agriculture (USDA) and the World Reference Base (WRB).

2. MATERIALS AND METHODS

This study was conducted at Taman Kekal Pengeluaran Makanan (TKPM) Ulu Chucoh located in Sepang district in the southern part of the State of Selangor, Malaysia (latitude 02°45'N and longitude 101°40'E) with the elevation of 36 m above the sea level. The average annual rainfall in Sepang is 2236 mm and humidity ranged from 80−84%. Daily temperature is ranged between 27.0−28.2°C throughout the year. The study area covers 9 ha. The soil type in the study site comprises of both the peat (average of 60 cm in depth) and admixture of peat and mineral soil underlying the peat (60−100 cm in depth). Three (3) soil profile pits was excavated within the study area using a transect approach (diagonal) considering the topography of the land, and the soil profile description was carried out. The soil morphological properties of the soil profile were described (Soil Survey Division Staff, 1993). Soil samples at different horizons were collected, air−dried, and sieved through a 2 mm sieve for further laboratory analysis such as the physical properties (sand, silt and clay, bulk density, particle density and porosity), chemical properties analysis (soil pH, CEC, SOC, Avail P and exchangeable bases). soil samples were also collected using the metal core ring (3) at each soil profile pits excavated making a total of 9 samples in the metal core ring. The bulk density was determined by gravimetric method, soil pH was measured with a glass electrode in soil solution suspension of 1:2.5 H_2O, the Walkley and Black wet oxidation method was used to determine organic carbon (Walkley and Black, 1934). The exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and N^{a+}) were extracted with NH_4OAc at pH 7.0 and the values was determined by atomic absorption spectrophotometer (AAS) (Ross and Ketterings 1995; Shamshuddin, 2006). After removing the excessive ammonium with ethanol, the soil was extracted with 0.05 M K_2SO_4 solution and the supernatant was used to determine the cation exchange capacity (CEC) by titration using 0.01 N Hydrochloric acid (HCl) (Jackson, 2005). The peat in the study area was further classified according to the United State Department of Agriculture (UDSA) Soil Survey Staff (2014), WRB FAO (2014) and the Malaysian soil taxonomy system (Paramananthan, 2010a).

3. RESULTS AND DISCUSSION

The morphological and physical properties of each soil profile pits (3) were analyzed and shown in Table 1, detailed description of each soil profile pits were also shown (Fig's 1 to 3 and Table's 2 to 4). The chemical properties analysis was presented in Table 5. According to the United State Department of Agriculture (USDA), WRB and Malaysian soil taxonomy, the soil in the study area was classified as *Histosols* (peat or organic soils) as observed by the field, physical and chemical properties analysis.

Morphological and Physical Properties

The 3 pedons (soil profile) excavated for this study was classified based on the morphological attributes. The soil showed a vary colour from dark brown 10 yr, 4/3 at top soil to gray 10 yr, 4/1 in the sub soil, from brown (10 yr, 4/3) to gray (10 yr, 5/1), and from very dark brown (10 yr, 3/2) to gray (10 yr, 5/1) for pedon 1−3, respectively (Table's 2 to 4 and Fig's 1 to 3). There was a slight variation at the peat layer of the pedon 3 compared to pedon 1 and 2. The peat colour (0−60 cm) were generally vary dark brown to very dark grayish brown in all pedons for this study. The dark brown colour at this layer (Peat) was a result of lower degree of decomposition and higher fiber content and high content of organic matter, while the colour of the substratum (mineral / admixture of mineral soil and peat underlying the peat layer) varied from dark gray to gray, and this was due to gleization (Oxidation) condition. The maturity of the peat in sepang was assessed based on field observation, the top layer of the peat mostly 0−20 cm is moderately decomposed (Hemic) compared to other depths which was well decom-

Table: 1
Morphological and physical properties of the peat in the study area

S/N	Depth (cm)	Colour	Level of maturity	Water table (cm)	Bulk density g cm^{-3}	Particle density	Porosity	Particle size distribution %			Soil textural class
								Clay	Silt	Sand	
pedon 1											
Oe	0–30	10 yr, 4/3	Hemic	45.00	0.24	2.64	0.91	46.30	51.40	2.30	
Oa	30–70	10 yr, 3/2	Sapric					59.90	39.10	1.70	clay
C	70–100	10 yr, 4/1	Clay					69.40	29.50	1.10	clay
pedon 2											
Oa	0–20	10 yr, 5/3	Hemic	48.00	0.22	2.64	0.91	48.50	50.10	1.40	
Oe	20–68	10 yr, 4/2	Sapric					61.40	38.40	0.02	clay
C	68–100	10 yr, 5/1	Clay					62.90	36.60	0.50	clay
pedon 3											
Oi	0–20	10 yr, 2/2	Fibric	32.00	0.22	2.64	0.91	48.00	50.50	1.50	
Oe	20–50	10 yr, 3/2	Hemic					59.10	38.40	2.50	clay
C	50–100	10 yr, 5/1	Clay					60.80	37.50	1.60	clay

d – dark, v.d.g – very dark grayish, d.g – dark grayish, v.d – very dark, N – non, St –sticky, pl – plastic, Oi – Fibric, Oa – Sapric, Oe – Hemic, C – Clay

Fig. 1. Soil profile for pedon 1 in the study area (TKPM Ulu Chucoh)

Fig. 2. Soil profile for pedon 2 in the study area (TKPM Ulu Chucoh)

posed (sapric) because the deposition of plant debris continually accumulates at the surface soil and it takes time to decompose (pedon 1 and 2). The pedon 3 shows a fibric maturity at the top layer of the peat (0–20 cm), showing that the soil at this layer is slightly decomposed (early stage of decomposition), then followed by the hemic maturity (intermediate between sapric and fibric) at 20–50 cm. The

Table: 2
Soil profile description of the profile (pedon 1) in the study area (TKPM Ulu Chucoh)

Location	Latitude 02°45'N and Longitude 101°40'E
Vegetation / land use	Vegetable and tuber cultivation
Peat depth	< 70 cm
Parent material	Clay
Topography / terrain class	Flat
Soil classification	(a) USDA soil taxonomy: Haplosaprist Histosol
	(b) FAO soil taxonomy: Dystric Histosols
	(c) Malaysian soil taxonomy: Topogambist Histosol
Depth (cm)	Descriptions
0–30	Brown (10 yr, 4/3), Hemic, fine root, fine, non–sticky, non–plastic, clear smooth.
30–70	Very dark grayish brown (10 yr, 3/2), sapric, very fine root, fine, non–sticky, non–plastic, clear smooth.
70–100	Dark gray (10 yr, 4/1), clay, very fine, sticky, plastic, clear smooth

Table: 3
Soil profile description of the profile (pedon 2) in the study area (TKPM Ulu Chucoh)

Location	Latitude 02°45'N and Longitude 101°40'E
Vegetation / land use	Vegetable and tuber cultivation
Peat depth	<70 cm
Parent material	Clay
Topography / terrain class	Flat
Soil classification	(a) USDA soil taxonomy: Haplosaprist Histosol
	(b) FAO soil taxonomy: Dystric Histosols
	(c) Malaysian soil taxonomy: Topogambist Histosol
Depth (cm)	Descriptions
0–20	Brown (10 yr, 5/3), Hemic, fine root, fine, non–sticky, non–plastic, clear smooth.
20–68	Dark grayish brown (10 yr, 4/2), sapric, very fine root, fine, non–sticky, non–plastic, clear smooth.
68–100	Gray (10 yr, 5/1), clay, very fine, sticky, plastic, clear smooth

Fig. 3. Soil profile description for pedon 3 in the study area (TKPM Ulu Chucoh)

groundwater table varied from 32 cm to 45 cm. The shallow water table shows its influence on the decomposition rate of the peat. The result obtained for the Sepang peat is similar to report by (Moore and Knowles, 1989; Handayani *et al.,* 2018). The differences between the organic horizons across the 3 pedons were a result from the eutrophic processes, the botanical origins, maturity rate (decomposition), water table, the depth of the peat and the land management in the study area (Baran 1994; Cayci *et al.,* 2000). The bulk density recorded in the study area was low and it varied from 0.22−0.24 g cm^{-3} in the three soil profile assessed. The variation was a result of the differences in the maturity level recorded in each soil profile (Table 1). The higher the maturity of the peat, the higher the bulk density of the peat and *vice−versa*. The high value of bulk density at pedon 1 showing hemic maturity was a result of the effect of cultivation or and the drainage condition at the point of the soil profile (it was well drained). Result obtained was similar to the peat of Riau, Indonesia (Hikmatullah and Sukaman, 2014). The soil textural class for the peat in Sepang (study site) showed a similar class which ranged from silty clay at the top layer of the peat (0−30 cm) to clay in the substratum (30−100 cm). The study revealed that the nature of mineral underlying the peat soil is a clayed and sulfidic substratum (>15% of clay).

Table: 4
Soil profile description of the profile (pedon 3) in the study area (TKPM Ulu Chucoh)

Location	Latitude 02°45'N and Longitude 101°40'E
Vegetation / land use	Vegetable and tuber cultivation
Peat depth	<70 cm
Parent material	Clay
Topography / terrain class	Flat
Soil classification	(a) USDA soil taxonomy: Haplosaprist Histosol
	(b) FAO soil taxonomy: Dystric Histosols
	(c) Malaysian soil taxonomy: Topogambist Histosol
Depth (cm)	Descriptions
0–20	Very dark brown (10 yr, 2/2), Fibric, fine root, fine, non–sticky, non–plastic, clear smooth.
20–50	Very dark grayish brown (10 yr, 3/2), hemic, very fine root, fine, non–sticky, non–plastic, clear smooth.
50–100	Gray (10 yr, 5/1), clay, very fine, sticky, plastic, clear smooth

Chemical Properties

The soil chemical properties of the peat in the study area (Sepang) was analyzed and the results obtained is shown in Table 5. Results obtained showed that there were variations in term of soil pH, soil organic carbon and matter, exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and N^{a+}), CEC, avail. P, base saturation, total carbon and the C/N ratio. Soil pH values obtained at all horizons of the excavated pedons showed a very acidic soil reaction with values ranging from pH 3.36–pH 5.11. Pedon 1 recorded a value of 3.67 at the top soil, and the substratum layer has a value of 4.35, pedon 2 and 3 showed a value of 5.11 and 4.08 at the top horizon, respectively, while their substratum or the mineral horizon was 3.93 and 4.29, respectively (Table 5). There is a similar trend among the 3 pedons showing a decreasing value with increasing depth until the last depth of the peat layer, thereafter, the values started increasing at the mineral (substratum) layer. The variation between the top soil and the sub soil in the 3 soil profile was related to the admixture of the peat with the mineral soil or the location of the peat (Andriesse, 1988). The results were similar to previous findings by (Suhardjo and WidjaAdhi, 1976; Mohamed *et al.,* 2002; Wahyunto *et al.,* 2010; Sari, 2013). Also, the finding showed that the acidity of the peat in the study site was caused by the high content of the organic acids which contains fulvic and humic acid (Andriesse, 1974). The organic carbon contents from all the identified horizons across the 3 pedons ranged from 7.09–13.44% (pedon 1), 9.17–13.81% (pedon 2) and 8.20–17.01% (pedon 3), and the organic carbon was high at the top layer of the 3 pedons (>12%). There was a decreasing trend with increasing depth down the soil profile as it was approaching the mineral layer (<12%). The result obtained was in accordance to Mohamed *et al.* (2002), who reported that the organic carbon was high in the surface soil than the sub surface layer. The high value reported at the top layer than the sub layer shows that the sub layers' were more decomposed than the top layer. In this study, the C/N ratio was quite high, ranging from 35.11–74.28 in all horizons across the 3 soil profiles. Result showed an increasing value for C/N ratio with increasing depth until the last horizon of the peat layer, then, the value start decreasing at the mineral layer underlying the peat soil layer. The increasing value down the depth at the peat layer indicates that the decomposition of organic matter was

Table: 5
Chemical properties of the peat soil in the study area

S/N	pH (H_2O)	SOC	SOM	Ca	Mg	K	Na	CEC	Base Sat.	Avail. P	C	N	C/N
		%				Cmol+ kg^{-1}			%	mg kg^{-1}	%		
pedon 1													
Oe	3.67	13.44	23.25	0.94	0.11	0.22	1.46	70.00	3.90	28.00	17.20	0.31	55.48
Oa	3.16	11.89	20.57	0.78	0.19	0.22	0.17	45.00	3.02	17.50	13.37	0.18	74.28
C	4.35	7.09	12.27	1.43	4.02	0.39	0.68	55.00	11.85	7.00	9.87	0.16	61.69
pedon 2													
Oa	5.11	13.81	23.89	3.14	6.65	0.54	0.86	95.00	11.78	94.50	16.70	0.41	41.21
Oe	3.90	10.97	18.98	2.81	1.44	0.27	0.25	70.00	6.81	45.50	13.40	0.21	63.81
C	3.93	9.17	15.86	1.38	3.37	0.30	0.90	40.00	14.88	23.70	11.20	0.19	58.95
pedon 3													
Oi	4.08	17.01	29.43	1.29	0.76	0.37	0.49	90.00	3.23	73.20	14.80	0.20	74.00
Oa	3.36	11.35	19.64	1.05	0.55	0.41	0.53	83.00	3.06	34.00	20.01	0.57	35.11
C	4.29	8.20	14.19	1.31	2.83	0.38	0.60	75.00	6.83	14.00	11.60	0.17	68.24

higher at the top layer than the sub layer. Meanwhile, the slow rate of decomposition in the deeper layer was a result of the water table hindering the rate of decomposition at that depth. Similar result was reported by Andriesse (1988).

The exchangeable bases recorded in all the 3 soil profiles ranged from low to very low, having values ranging from 0.78–3.14 $cmol_+ kg^{-1}$ (Ca), 0.11–6.65 $cmol_+ kg^{-1}$ (Mg), 0.22–0.54 $cmol_+ kg^{-1}$ (K) and 0.17–1.46 $cmol_+ kg^{-1}$ (Na). The highest values for the exchangeable bases was recorded in pedon 2 (Table 5). The high content of the bases in this pedon shows the relationship between the bases and the soil pH (exchangeable bases are pH dependent), *i.e.* the higher the soil pH, the higher the soil exchangeable bases would be. Although, the values recorded at all horizons of the 3 pedons were still low for sustainable farming. The base saturation reported from this study was also low with values ranging from 3.02–14.88%. The low content of the bases and the base saturation recorded in the study area is typical for peat because of the acid nature of the peat, and the result was similar to Driessen and Suhardjo (1976). CEC values at the peat layer (0–60 cm) in all the 3 soil profiles were high ranging from 45–90 $cmol_+ kg^{-1}$. Peat are high in CEC because they are pH dependent (negative charge of the carboxyl and hydroxyl groups of the phenolic acids) (Driessen and Soepraptoharja, 1974). The study revealed that the CEC of the soil in the study area is influenced by the organic matter content. Andriesse (1988), quoted Volarovich Churaev (1968), that ion adsorption and the exchange is associated with the hydrophilic colloids of the organic soils *i.e.* the humic acids. Also, Tie and Kueh, (1979), reports that peat are highly saturated with hydrogen ions. Result obtained was similar to the peat soil in Sarawak, Malaysia. Available phosphorus extracted using the Bray and Kurt method 2 showed a high value at the top horizons and it tend to decrease with increase in depth. The values obtained from this study ranged from 7.0–28 mg kg^{-1}, 23.70–94.50 mg kg^{-1} and 14.0–73.20 mg kg^{-1} for pedon 1, 2 and 3, respectively. The highest content of available P was found at the top horizons in all the 3 soil profile, whilst the lowest value or content was recorded at the last depth in all the pedons analyzed. The results were similar to the range reported in peat of peninsular Malaysia (Kanapathy, 1976).

Classification of the Peat Soil in the Study Area

The classification of the peat in the study site (Sepang) was based on the field observations and the data collected from the laboratory analysis according to the United State Department of Agriculture (USDA) soil taxonomy system (Soil Survey Staff, 2014), WRB (FAO, 2014) and the Malaysian soil taxonomy system, revised second edition (Paramananthan, 2010a). The comparison between the USDA, WRB, and MST for the criteria's used for peat is shown in table 6. The classifications criteria were definition of peat, the kind of OSMs, depth of the peat and the loss on ignition. The 3 soil systems agreed on the definition of the OSMs, but the revised second edition of the Malaysian soil taxonomy system added the criterion of loss on ignition (>65%). Based on the organic matter content of the soil in the study area, the soil fulfilled the criteria of a peat having above 12% of organic carbon. The soil in the study area are classified as topogambist and hemic topogambist due to the thickness (depth) of the peat ranging from 50–150 cm. The study revealed that the cultivated peat in the study area have a maturity level of fibric–sapric–hemic. The peat was also well drained (Folist). According to the depth, the soil in the study site is classified as a shallow peat (50–100 cm). Further, the nature of the mineral soil underlying the peat layer (substratum) in the study area is classified as clayed and sulfidic substratum (>15% of clay). The capability class of the soil in the study area is class 4, having met the criteria by showing four degree of limitation.

Potential of the Peat in the Study Area for Agricultural Development

The assessment (classification and characterization) carried out on the peat soil of the study area (TKPM Ulu Chucoh, Sepang district of Selangor, Malaysia) has shown that the peat soil in the area has a good potential for sustainable agriculture based on the morphological physical and chemical properties. Although, its management should be considered based on the specific characteristics of the type

Table: 6
Comparison of the criteria used for organic / peat soil in Sepang, Malaysia

Soil characteristics	World reference base (FAO, 2014)	Keys to soil taxonomy 11th edition (Soil Survey Staff, 2014)	Malaysian soil taxonomy Rev. 2nd Edition. Paramananthan, 2010a
1. Kind of OSM			
a Definition of OSM	Saturated	Saturated	Saturated
b Kind of OSM	Sapric	Sapric	Sapric
2. Classification based on definition	Soil Group–Histosol	Order–Histosols	Order–Histosols
	prefix–Sapric	Sub order–Folist	Sub order–Folist
	Sufix–Dystric	Great order–Sulfihemist	Great order–Topogambist
		Sub group–Haplosaprist	Sub group–Hemic
		Family–NA	Family–Kilat
3. Soil phase	NA	NA	Shallow

of crops to be cultivated (Las *et al.,* 2011). However, based on the results obtained from this study, using the degree of limitations and classes as proposed by Maas *et al.* (1979), the capability class of the peat in the study area is class 4 (Moderate), having met the criteria by showing four degree of limitation. The suitability of the peat for crops is determined based on factors like maturity of the peat, thickness of the peat, mineral contents and the substratum underlying the peat soil. According to Ritung *et al.* (2011), the peat in the study site, having a hemic‒sapric maturity, clayey substratum, and the thickness of the peat less than 100 cm was classified as moderately to marginally suitable for both annual and perennial crops. Further, due to the low contents of some major soil nutrients (soil pH, exchangeable bases, and available P) required for the optimum growth of the crops, the peat in the study site needs some inorganic fertilizers based on the deficiencies in the soil and some ameliorants to improve and maintain the fertility of the peat in the study area. The water management would also be required and implemented by managing the ground water table to 50 cm deep in order to maintain the moistness and reduce the excess water in the study area.

4. CONCLUSIONS

There were variations in term of the soil colour, soil pH, thickness or depth of the peat, the maturity level or decomposition rate, bulk density, depth of the ground water table and the chemical properties as a result of different factors the like temperature, climate, decomposition process, chemical composition of the soil in the study area (peat), the water table level, age of the peat, inorganic soil underlying the peat layer and texture of the soil. The peat soil in the site was classified as shallow peat (<100 cm) which is more decomposed, well drained and low bulk density. The peat is a dystric peat due to the acid reaction. Finally, the findings from this study revealed that the cultivated peat in the study area is moderately to marginally suitable for annual and perennial crops, but it will require the applications of some ameliorants and fertilizer to improve and maintain the fertility of the soil. Also a good water management can be considered to maintain the soil moistness and avoid excess water across the field.

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